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Disaster Mitigation and Preparedness in a Changing Climate

A Synthesis Paper

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DISASTER MITIGATION AND PREPAREDNESS IN A CHANGING CLIMATE

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IN A CHANGING CLIMATE

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DISASTER MITIGATION AND PREPAREDNESS IN A CHANGING CLIMATE

I. Introduction

This synthesis paper will outline the issues and the latest scientific conclusions about climate change and severe weather events. The paper will provide information about the relationship between a changing climate and the frequency and severity of extreme weather events especially in the northern latitudes. It will discuss policies, means and mechanisms which will reduce the negative impact of extreme weather events and related natural disasters on human populations and infrastructure, with particular emphasis on the Canadian situation. Finally, it looks ahead at the continuing need for scientific, engineering, political and administrative actions and processes that will facilitate mitigation in a changing climate.

II. Summary of the Scientific Background of Climate Change

Most scientists agree that human economic activities are having a discernible and increasing influence on the climate, which will create a number of positive and negative results for the world's citizens and ecosystems.

Life on Earth is possible because of a natural greenhouse effect in which the Earth's atmosphere traps outgoing radiation, thus causing the overall temperature of the Earth to be some 33°C warmer than it would otherwise be (i.e., the present global mean temperature of +15°C would be –18°C without the "greenhouse effect"). The gases that contribute to this effect are called greenhouse gases and include water vapour, carbon dioxide (CO_2), methane, nitrous oxide, chlorofluorocarbons (CFCs) and ozone. Of these, the most prevalent human-produced gas is CO_2, which comes primarily from the burning of fossil fuels.

Scientists have found that for several thousand years prior to industrialisation, around 1750, a steady balance of about 280 parts per million by volume (ppmv) was maintained in the concentration of carbon dioxide in the atmosphere. Since the industrial revolution, as more fossil fuels have been used to produce energy to fuel economic growth, concentrations of CO_2 have increased by about 30%[1] to a current level of 360 ppmv. Computer projections show that if the world continues as it is now, by 2100 concentrations could be nearer 700 ppmv. This could increase global average temperatures by as much as 4.0°C. Although this does not sound dramatic, one need only recall that during the last ice age global average temperatures were only some 6°C cooler than they are today. Scientists predict that the warming will not be evenly distributed and that the polar regions and inland temperate zones, such as the Canadian prairies, will experience even higher temperatures and in some regions, less precipitation.

[1] If other human-influence greenhouse gases are expressed as CO_2 equivalent, the increase due to human activities is about 50%.

Warmer temperatures will gradually cause polar ice to melt. Combined with the expansion of ocean water due to warmer water temperatures, sea levels could rise to a level that will threaten coastal areas and small island nations. As well, with more thermodynamic energy in the global system, there will likely be an increase in occurrences of extreme weather events, leading to threats to human safety and property damage. Climate change can be argued to be the most pervasive and far-reaching environmental issue ever dealt with by the international community.

In 1988, the Intergovernmental Panel on Climate Change (IPCC) was formed by the World Meteorological Organisation (WMO) and the United Nations Environment Programme (UNEP). It brought together a broad range of government and non-government experts to assemble and assess the most recent available scientific knowledge and to determine what is known and not known about the climate system and climate change. Some 2000 scientists contributed to the most recent report, the *1995 Second Assessment Report*, which concluded that, "The balance of evidence suggests a discernible human influence on global climate"[2].

III. The Kyoto Protocol - Delaying Climate Change

As the scientific research effort gained momentum and the conclusion accepted that climate change was the inevitable outcome of increasing greenhouse gas emissions, a number of important international intergovernmental conferences were held from the mid-1980s to the early 1990s. Table 1 shows a chronology and summary of the key events.

TABLE 1: The Road to Kyoto[3]
A timeline of scientific research and conferences that led to the Kyoto Protocol

1896	Svante Arrhenius, a Swedish chemist, predicts carbon dioxide emissions from burning of coal will lead to global warming.
1957	Revelle and Seuss, scientists with the Scripps Institute of Oceanography, report that much of the CO_2 emitted into the atmosphere by industrial activities is not absorbed by the oceans, as some researchers had proposed. They described the build-up of carbon dioxide in the atmosphere as "a large-scale geophysical experiment" with the Earth's climate.
1958	Keeling, a scientist with the Scripps Institute, initiates the first reliable and continuous measurements of atmospheric carbon dioxide at Hawaii's Mauna Loa Observatory.
1972	Stockholm: first U.N. Conference on the Human Environment where human induced climate change was identified as a pressing issue. The United Nations Environment Programme founded.

[2] Paraphrased from Russell, Doug, and Toner, Glen, *Science and Policy when the Heat is Rising: The Case of Global Climate Change Negotiations and Domestic Implementation.* A Paper for the CRUISE Conference on Science, Government and Global Markets, Ottawa, October, 1998.
[3] From Russell and Toner.

1979	Geneva: first World Climate Conference: launched the World Climate Program to co-ordinate global research on climate and climate change and collect meteorological data.
1985	Dr. Joe Farmer, British Antarctica Survey, discovers a hole in the ozone layer over the Antarctic. His ground-based measurements are later confirmed by satellite images.
1985	Villach (Austria) Conference: issued a warning that "Many important economic decisions are based on the assumption that past climate is a reliable guide to the future. This is no longer a good assumption."
1987	Montreal Protocol on chemicals that deplete the ozone layer signed by 24 countries. They agreed to freeze consumption of CFCs and halons at 1986 levels, and reduce consumption by 50 percent by 1997.
1988	The Intergovernmental Panel on Climate Change (IPCC), made up of the world's leading climate scientists, is established by the U.N. Environment Programme and the World Meteorological Organisation to assess the scientific research on climate change and its environmental impacts.
1988	Toronto: The Conference on the Changing Atmosphere calls for a 20 percent reduction in carbon dioxide emissions.
1990	Geneva: First assessment report of the IPCC is endorsed at the Second World Climate Conference by more than 500 scientists and world leaders. A call is issued for an international agreement to mitigate global warming.
1992	Rio de Janeiro: One of the results of the United Nations Conference on Environment and Development (UNCED) was that 154 nations signed the U.N. Framework Convention on Climate Change, voluntarily agreeing to stabilize greenhouse gas emissions at 1990 levels by the year 2000.
1995	The IPCC, representing the consensus of the world's climate scientists, concludes that "...the balance of evidence suggests that there is a discernible human influence on global climate." It also concludes that the net benefits of greenhouse gas mitigation exceed the costs in many countries at least for the initial reductions.
1997	Warmest year on record since scientists began keeping accurate meteorological logs in 1860. The next two warmest years are also in the same decade: 1995, 1990.
1997	Kyoto, Japan: 159 nations negotiate a treaty setting out legally binding reduction targets averaging 5% below 1990 levels for industrialized countries for six greenhouse gases.
1998	Preliminary measurements indicate that 1998 is the warmest year on record in Canada.
Adapted from IISD, *A Guide to Kyoto: Climate Change and What it Means to Canadians*: 19-20.	

In spite of a small number of primarily American scientists who are sceptics there is a general scientific consensus regarding the influence of human activities on the climate. The significance of the Conference of Parties'[4] third meeting in Kyoto in December 1997

is the commitment to reducing greenhouse gas concentrations below 1990 levels with the aim of slowing the rate of climate change. However, even with the reductions in greenhouse gas emissions agreed to in Kyoto, there will continue to be changes in climate to which Canadians will have to adapt. In Canada's case, because of our high latitude location, the impact of the changes may be particularly severe.

Canadian authorities have organised the domestic science assessment process around Canada's Climate Program Board (CCPB). The CCPB has prepared reports on the state of the science, impacts of climate change on Canada, and mitigation and adaptation response options. The four federal natural resources departments (Environment, Natural Resources, Agriculture and Agri-Food, and Fisheries and Oceans) agreed to work together on joint projects and implement a framework for sustainable development science and technology in the natural resource sectors.[5]

A summary of the scientific information and data indicates that Canada's average temperature is about 1°C warmer since 1895, and there has been a discernible increase in the frequency of winter storms throughout the 20th century. In 1995, approximately 89% of total greenhouse gas emissions (GHGs) in Canada were attributable to transportation and fossil fuel production and consumption. In Canada, 1998 is shaping up to be the hottest year on record: the average national temperature for the first six months was 2.7°C above normal and parts of the Northwest Territories experienced temperatures more than 5°C above normal. Because of its size and high latitude location, Canada is projected to experience greater temperature changes than most regions of the world. As a coastal and northern country, and as a renewable resource producer in the forestry, agriculture and fisheries sectors, Canada is more vulnerable than most to damage from climate change.

In the Kyoto Protocol, Canada agreed to reduce emissions of greenhouse gases to 6% below 1990 levels by between 2008 and 2012. In his second report in 1998, the Commissioner of Environment and Sustainable Development audited the federal implementation effort on key international environmental agreements for the period between the Rio de Janeiro (1992) and Kyoto (1997) meetings. The audit found an inadequate implementation effort, characterised by a lack of co-ordination among federal departments, a lack of federal-provincial co-operation and an overall management structure that lacked accountability. In a meeting immediately following Kyoto, federal, provincial and territorial leaders agreed to renew the implementation effort.

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[4] At "the Earth Summit" in Rio de Janeiro in 1992, 154 states plus the European Community signed the United Nations Framework Convention on Climate Change. The "Conference of Parties" comprises the states that have ratified the Convention (175 as of July 1998) and is the supreme authority of the Convention.

[5] Environment Canada (EC) develops the global and regional general circulation models in Canada and researches climate change, including climate change impacts and adaptation research. It also led the work on the Canada Country Study, the first national assessment on climate change impacts and adaptation. Natural Resources Canada (NRCan) leads federal government research on energy efficiency, alternative fuels, renewable energy and the role of forests in climate change. In addition, the interdepartmental Program of Energy Research and Development (PERD) helps co-ordinate the energy R&D programs of twelve departments. Since April 1996, PERD has increased its support for research related to energy efficiency and climate change.

To that end, the federal government clarified the respective roles of Environment Canada and Natural Resources Canada, created a Federal Climate Change Secretariat and established the Climate Change Action Fund (CCAF) to which was committed $150 million over three years to help Canada meet its commitments under the Kyoto Protocol. The Fund will enable concrete early action to reduce greenhouse gas emissions, lay the foundation for meeting Canada's commitments under the Kyoto Protocol, and engage Canadians in becoming part of the solution. The Secretariat will oversee a multi-stakeholder consultation initiative to examine the impacts, costs and benefits of the Kyoto Protocol, including adaptive measures, and determine immediate and longer-term actions to provide sustained reductions in greenhouse gas emissions. The goal is to have a "step-by-step" national implementation strategy by the end of 1999 and, hopefully, a plan to apportion responsibility for meeting Canada's national targets[6].

In the inter-provincial and industrial arenas, the federal government has agreed to not do anything that will disadvantage Canada's competitive position in the global economy and that a CO_2 reduction strategy to meet the Kyoto Protocol must not impact unfairly on any particular region. Some provinces have stated that they would not launch an emissions reduction campaign until the USA ratified the Kyoto Protocol[7]. Some in the fossil fuel sector, particularly some big coal and petroleum companies and auto producers are leading the charge against climate change science and policy. Major industrial consumers of fossil fuels in the petrochemical and utilities sectors, as well as the transportation sector, will likely experience significant impacts on their operations. Hence, some umbrella industry associations such as the Business Council on National Issues have also taken positions critical of the climate change science and policy proposals. It should be noted that the International Business Council for Sustainable Development and some of the large energy companies such as British Petroleum and Shell have indicated that they will be part of the effort to reduce emissions.

While some members of the fossil fuel and other energy-related industries are pushing the federal government from one side, other industrial sectors such as the insurance industry, which is suffering huge losses due to extreme weather events, is pushing back. So are other sectors that stand to gain from an energy efficiency and alternative fuels strategy, and those that are beginning to sense their own vulnerability from current climate variability. Also, public opinion is slowly moving as the general public begins to better comprehend the issues and what is at stake[8]. It is in this difficult environment of opposing national and international stakeholders that critical decisions must be taken and

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[6] From Russell, Doug, and Toner, Glen. *Science and Policy when the Heat is Rising: The Case of Global Climate Change Negotiations and Domestic Implementation*. A Paper for the CRUISE Conference on Science, Government and Global Markets, Ottawa, October, 1998, and Government of Canada News Releases, *Federal Government Takes Concrete Action on Climate Change* and *Backgrounder on Climate Change Action Fund*, #98/76(a), October 19, 1998.

[7] On November 12, 1998, the United States announced that it would agree to the Kyoto Protocol.

[8] In a 1998 Environics poll "Respondents were asked whether strong action should be taken on climate change even though scientific uncertainty remains and action could involve major costs". In Canada, a strong majority (67%) said government should assume the worst and take immediate steps to address the problem. Last year, 61% said action should be taken.

strategies formulated for the reduction of greenhouse gases to the levels committed to in the Kyoto Protocol.

At the same time, means and mechanisms must be found to adapt to the results of inevitable climate change since the Kyoto commitments will only slow the change by about a decade. One key aspect, the development and implementation of a national strategy of prevention, mitigation and preparedness for extreme weather events and the concomitant natural disasters, must be an essential component of a climate change adaptation strategy.

IV. What We Know, What is Predicted and What We Suspect About Extreme Weather Events in a Warmer World

The observed global mean temperature increase of the past century of about 0.5°C, and the regional and vertical patterns of temperature changes, have been similar to those projected by general circulation models which estimated probable effects of observed increases of greenhouse gases and aerosols to date. This has also been reflected in observed changes in some extreme weather events.

How would climate change affect the frequency and severity of extreme weather events? First, it is believed that the additional warming will change the distribution of heat and thus the flow of energy through the climate system. This will, in turn, alter the circulation patterns of the atmosphere and the oceans, and it will also modify the hydrological cycle by which water is circulated between the Earth's surface and the atmosphere. As a result, the position of many of the world's major storm tracks could shift significantly.

Secondly, it is expected that a warmer climate would affect the physical processes that generate different types of extreme weather events. A virtually certain outcome of a rise in global temperature is a widespread increase in the amount of water that is moved through the hydrological cycle. Consequently, more moisture will be available in the atmosphere to fall as rain or snow. General circulation models indicate that a warmer atmosphere will increase the amount of moisture transported into the middle and high latitudes of the Northern Hemisphere. These models also suggest that the additional precipitation will likely occur in heavier falls rather than in more snow or rain days.

As will be discussed later in this section, death and injuries, and insured and economic losses from natural disasters are increasing very rapidly. There are some regional evidences of trends in climatic extremes during the past few decades which could help explain some of these rapidly rising disaster loss trends[9].

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[9] A number of these observed changes in extremes are cited by IPCC (1995) especially in Volume 1 - The Science of Climate Change, Chapter 3. However, IPCC's cautious conclusion is that "...there are inadequate data to determine whether consistent global changes in climate variability or extremes have occurred over the 20th Century".

Extreme Weather-Related Events:

Rainfall Intensities: Among the regionally observed trends, well confirmed by long-term reliable data, are increases in the frequency of extreme rainfall events in the USA, Japan and northern Australia, and the northwest coast of India.[10]. However, there has been no similar detectable trend in shorter period records to 1989, in China or the former Soviet Union. Severe thunderstorms, which can produce heavy rain or hail, and tornadoes, remain a particularly difficult issue for general circulation models because of their small geographic scale. It seems likely that the number and intensity of severe thunderstorms will increase in most areas in a warmer climate

Storm Intensities: Determining changes in frequency and severity of extra-tropical storms in temperate zones is fraught with difficulty because a number of different criteria of intensity can be used (e.g., central atmospheric pressure, strongest winds, heavy rains, etc.) each presenting problems in obtaining long-term consistent sets of data or weather maps. Evidence on how storminess will change in a warmer climate is conflicting and conclusions regarding severe storms, must be viewed with caution.

Empirical studies referenced by IPCC present evidence of significant recent increases in the numbers of severe North Atlantic storms[11]. Also indicated are abrupt increases in recent North Pacific storm intensities, and a Northern Hemisphere increase in size and intensity of extra-tropical cyclones. Of particular interest to Canadians is a reported marked increase since the 1970s of very intense winter storms in the Northern Hemisphere (see figure 1). In eastern North America, seven of the eight most intense storms that developed in the past 50 years occurred in the most recent 25-year period.

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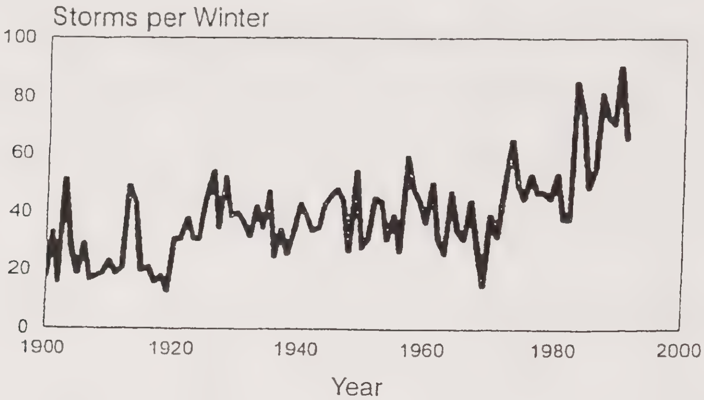
[10] For example, Tom Karl of US National Oceanographic and Atmospheric Administration, and colleagues, reported in *Nature* (1995) that there was a highly significant (20%) increase over USA in the summer season in the proportion of rain occurring in heavy rain days (>50.8 mm) over the period 1911 to 1992. This was also reflected in annual statistics. In a more recent paper these authors showed that the proportion of the USA that has had a much greater than normal amount of precipitation in extremely heavy one day events (>50.8 mm) has steadily increased over the century. They calculate that this result has a less than 1 in 1000 chance of occurring in a quasi-stationary climate and thus is a manifestation of a changing climate.

[11] For example, Bouws, E. Janninie, D., and Kouen, G.J. (1996), found a higher frequency of extreme storms in the North Atlantic winters since 1988/1989 than at any time since 1880. Lambert (1996) found an increase in severe winter cyclones near the Aleutian Low and the Icelandic Low after 1980.

Figure 1: Frequency of Intense Winter Storms in the Northern Hemisphere[12]



For tropical cyclones and hurricanes, data from the World Meteorological Organisation (WMO) yield no evidence of changes in frequency and intensity on a global basis. At the same time, the frequency of North Atlantic hurricanes declined over the period 1970-1987 while those in the western Pacific increased. These changes are much more likely to be due to the relatively persistent warm El Niño Southern Oscillation (ENSO) events of the past two decades, than due to greenhouse forcing of climate. ENSO events tend to depress Atlantic hurricane activity and change the distribution of tropical cyclones in the Pacific. As discussed more fully later in this section, this pattern could become more persistent since some research suggests that the past 15 years of unusual ENSO behaviour is very unlikely to be part of natural variability and may well be reflecting greenhouse gas forcing.

Hail, Tornadoes and Wildfire: There have been few studies of changes in hail occurrence, but an increase in summer hail severity in France has been reported, associated with warmer night-time temperatures. Other small-scale, intense disturbances such as tornadoes have notoriously serious reporting difficulties, but increased frequency of tornadoes on the Canadian Prairies appears to be related to above normal spring and summer temperatures, increasingly evident in the past two decades. This implies that the number of tornadoes may increase in the Canadian Prairies as a result of climate change.

Wildfire increases in Yellowstone National Park from 1985-1990 have occurred as a result of trends in climatic conditions. In the boreal forests of central and northwestern Canada, the area annually disturbed by fire and insects has doubled in the past two decades compared to the previous 50-year period. This is related to statistically significant winter, spring and summer warming trends and probably more lightning. Other factors such as tree age, and fire fighting policy also may have contributed to this increase.

Floods and Droughts: Different regions of Canada can be affected by rainstorm floods, ice-jam floods and snowmelt floods. A shorter winter season under climate change may

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[12] Lambert, S.J. (1996).

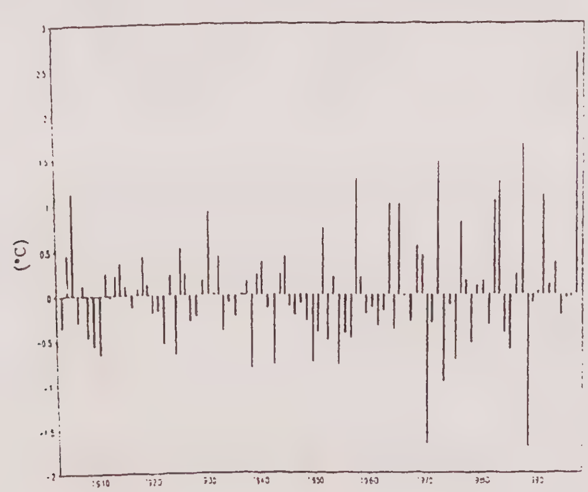
result in a reduced snowpack in many areas and thereby a reduced risk of snowmelt and ice-jam floods. The main concerns about increased flooding result from the fact that a warmer atmosphere can hold more moisture, and precipitation is expected to increase as a result. As well, the precipitation is expected to become more intense over smaller areas, which suggests greater flooding problems especially in smaller catchment areas.

Conversely, regarding droughts, the concem is that with an increase in heavier rainfall events, the number of dry days between events may increase and drought will become more severe. This effect could be worsened by higher air temperatures and increased evaporation. Some general circulation model studies show reduced soil moisture values over the mid-North American continent, suggesting more frequent droughts in the future.

For floods and droughts, other forms of change, such as to land use, are also important factors in the changing severity of extreme weather events. For example, the reduction of woody vegetation, the urbanization of watersheds, increased areas of impermeable surfaces for highways, and some other land use changes, increase the amount of precipitation that quickly becomes surface runoff. Small rivers and streams in affected regions became increasingly "flashy", with higher peak floods and less flow in dry periods.

Effects of El Niño: Since the mid-1970s, El Niños have been both more frequent and more persistent (see figure 2). There has been an undeniable upsurge, at the same time, in both the frequency and intensity of severe weather events. This change in ENSO behaviour can account, at least in part, for many of the weather extremes in the past couple of decades. As noted above, the changing distribution of tropical cyclones and hurricanes is strongly influenced by El Niño and the opposite effect, La Niña. Research is beginning to indicate that climate change may be making the ENSO events more frequent, more persistent, and more intense.

Figure 2: July Sea Surface Temperature Anomalies in the Southern Pacific (ENSO Region 3) (An Indicator of ENSO Intensity)



The United Nations Environment Programme (UNEP) and the US National Center for Atmospheric Research (NCAR) jointly sponsored a workshop in Boulder, Colorado, in July 1998 on the *"Review of the causes and consequences of cold events, A La Niña Summit"*. The workshop concluded that the El Niño 1997-98 phase was over and the less frequent phenomena La Niña, was under way. La Niña is suspected of encouraging more destructive hurricanes like "Georges" which killed over 300 people and caused more than US$5 billion in damages, and recently, "Mitch" which killed over 10,000 in Central America.[13][14] ENSO events, El Niño and La Niña, are increasingly predictable due to research under the World Climate Research Programme and this provides a basis for more reliable seasonal predictions, at least for western Canada and lower latitudes.

Disaster Losses:

Compilation of reliable global or even national disaster loss statistics is a notoriously difficult task in part because there are no standardized approaches to such estimates. Economic loss figures sometimes include indirect costs such as loss of trade, while others include only direct damages. In addition, some loss estimates may be inflated to qualify for government financial disaster assistance[15]. While reservations about the data should be kept in mind, there are good indications that total global economic losses have been rising at a remarkable rate since the early 1960s. Average direct economic losses in constant dollars have risen from about $1 billion US per year in the 1960s to over $50 billion per year in the 1990s. Combined losses due to natural and human-induced catastrophes were estimated by Munich Reinsurance for 1994 at $65 billion and for 1995 at $180 billion. The huge 1995 losses included the Kobe, Japan earthquake estimated at about $80 billion. Only $2 to $5 billion of these totals were from human accidents, the rest from natural disasters. Although only 20% of these economic losses were in low income countries, the impact expressed as percentage of their GNP was 5.5 times that of high income countries.

The Centre for Research on Epidemiology of Disasters (CRED) estimates a total of 1.9 billion people were affected by natural hazard disasters from 1986-1995.[16] This is about one third of the present global population (although some of the people affected may have been counted several times having been visited by more than one disaster over the

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[13] A review of the El Niño damages of 1997-98 was undertaken at a workshop in Guayaquil, Ecuador in late 1998, organized by the World Meteorological Organization.

[14] Research into these weather-related events is attracting support from other sources: a United Nations fund established by Ted Turner, Co-chairman of Time Warner Inc., has provided $US 650,000 for a UNEP project, "*Reducing the Impact of Environmental Emergencies Through Early Warning and Preparedness - The Case of El Niño Southern Oscillation*".

[15] Perhaps the most reliable statistics are compiled by the insurance industry, particularly the major re-insurers. Other sources of information are the Centre for Research on Epidemiology of Disasters (CRED), University of Louvain, Belgium, and the Office of Disaster Assistance of US AID. The Secretariat for the International Decade for Natural Disaster Reduction, Geneva and the Japan National Land Agency have provided valuable compilations and analyses.

[16] Cited in *Implications of Climate Change for Natural Hazards*, a presentation given by James P. Bruce (then Chair of the Canadian Climate Program Board), at the Natural Hazards Society, Toronto, 1996

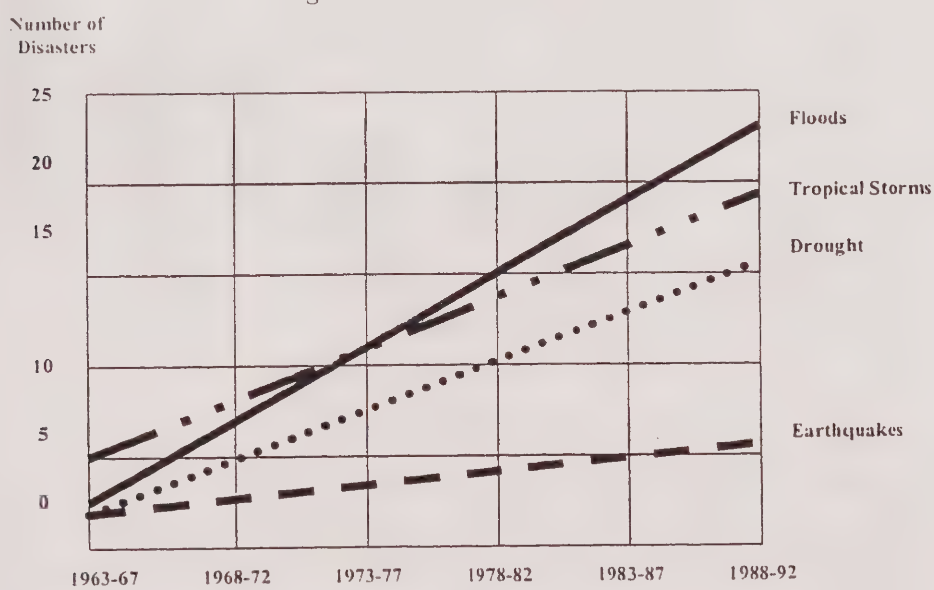
decade). Numbers affected have risen an average of 6% per year over the past two decades, triple the global population growth rate.

Disaster deaths over the past decade were estimated by CRED at 760,000 worldwide.[17] While both economic losses and numbers affected have been surging ever higher, the number of deaths since the mid-1960s has increased more slowly, probably due to improved mitigation, warning and preparedness systems. It is important to note that between 1985-1992, 88% of deaths were in low income countries.

There is a great disparity between categories of hazards and the global number of deaths and persons affected however, climate-related disasters (storms, floods and droughts) dominate the picture.

The analysis of disaster loss trends which has the greatest value in attempting to assess whether climate-related causes are increasing disproportionately, was that done by the IDNDR[18] Secretariat for the World Conference on Natural Disaster Reduction, Yokohama, 1994. It provides data on numbers of "major" disasters from 1963-1992[19] (see figure 3).

Figure 3: World Disaster Trends



Over the period, for disasters exceeding 1% of GNP of the affected country, the number of earthquake disasters doubled or tripled, but droughts increased by five to seven times; floods were up eight to 12 times; and tropical storms about four times. For disasters which affected more than 1% of population, floods and droughts also showed the greatest rate of increase, more than twice as rapid as the doubled number of tropical cyclones.

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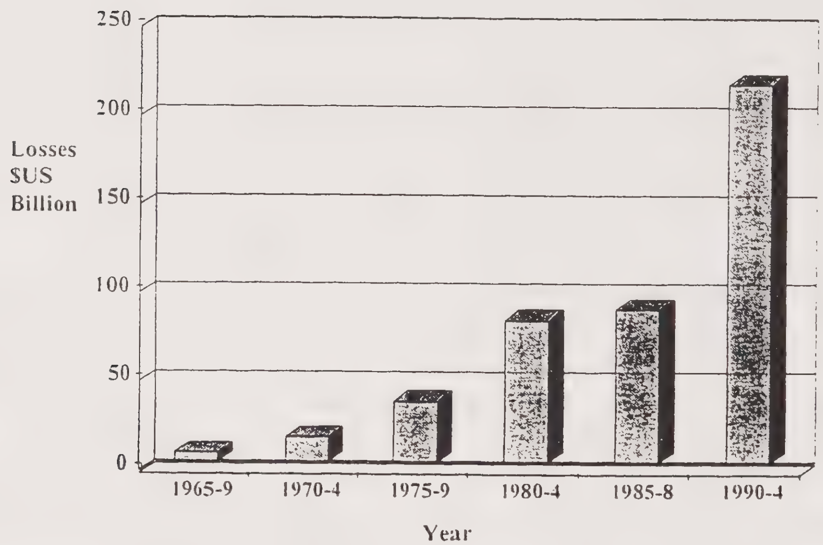
17 Bruce as above.

18 The United Nations International Decade for Natural Disaster Reduction

19 "Major" is defined as:damages of more than 1% of annual GNP of the affected country, number of affected people exceed 1% of the population, and number of deaths greater then 100.

Further evidence of the much more rapid increase of major climate-related disasters is found in data from Swiss and Munich Reinsurance, which indicate that annual economic impacts for major windstorm events (greater than $500 million damages) increased 10 fold between the 1960s and the early 1990s (see figure 4).

Figure 4: Five Year Global Insured Losses, 1965-1994 (US 1992 Billion $)



Global GDP (trillion):

1965	1970	1980	1990
$8.5	$10.5	$15.5	$21

Sources: National Land Agency, Japan & Munich Re.

A fifty-fold increase in direct economic disaster losses from 1965 to 1994 far outstrips the trebling of total global GNP during the same period. It is also a far faster rate of increase than the growth of the world's population from about three billion to 5.6 billion during the same period.

If it is considered that the increased earthquake disaster losses is generally proportional to the global increase in population and exposed infrastructure, why are climate related losses increasing many times more rapidly? It is difficult to determine whether there is a greater rate of economic development in areas affected by floods and storms, than those affected by earthquakes however, in many parts of the world, these are basically the same regions, and it is unlikely that differential development could account for the large differences in rate of change. Thus, the much more rapidly increasing rate of loss from climatically related disasters such as from floods, storms and droughts may indeed suggest that these latter hazards may be increasing in frequency and severity.

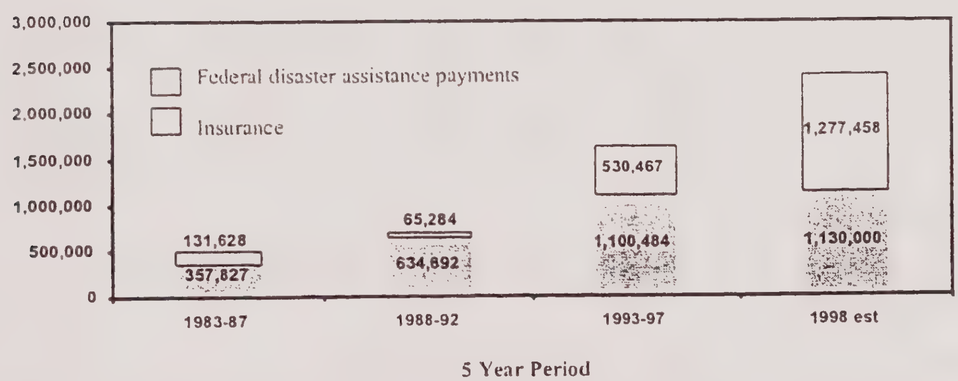
In Canada, Table 2 and figure 5 show that insured losses caused by severe weather-related events match or exceed those averages portrayed above for the rest of the world rising over 30 times from losses in 1984 of about $39 millions to the huge loss in 1998 exceeding $1,450 millions.

Table 2; Disaster Losses in Canada, 1984 – 1998 [20]

YEAR	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98
LOSS $MIL.*	39	101	12	170	87	14	16	484	94	255	200	376	760	205	1450

Note: Loss figures are insured losses and do not include all economic losses such as residential losses in floods which are not insurable.

Figure 5: Costs of Weather-Related Disasters to Federal Government and Insurers, 1983-1998 ($000s)



Note that the insurance industry portion for the 1993-97 interval includes an estimate of $100 million for 1997; federal disaster assistance payments and insurance industry totals for 1998 are incomplete.

Summary of Past Changes: From this brief review the following points emerge:

1. Global losses in weather-related disasters have escalated enormously over the past few decades, three times as rapidly as for earthquake disasters and a similar trend is apparent in Canada.
2. Three factors appear to have caused this increasing disaster toll:
   a) increased population and infrastructure exposed to the hazards;
   b) changes in land use affecting flood and drought frequency and;
   c) increases, at least regionally, in frequency of heavy precipitation and severe extra-tropical storms.

[20] From Angus Ross, Sorema Reinsurance.

3. The relative importance of these three factors is difficult to determine from available data.
4. Disaster mitigation measures, especially warning and preparedness systems for floods and storms, and safer building design for earthquakes, high winds and snowloads, particularly in economically developed countries, have limited the increase in numbers of deaths, but appear not to have had a major impact on economic losses or numbers of affected people.

Projections of extreme weather events for Canada: The northern geographic location of Canada and its huge surface area covering arctic tundra, interior plains and extensive coastlines will expose the country to extremes of most types of weather systems creating a high probability of related disastrous events. While projections are notoriously difficult, most studies have projected that CO_2-equivalent concentrations in the atmosphere will double from pre-industrial times to the middle of the next century. Without major intervention under the UN Framework Convention on Climate Change, the Second Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) indicated the following projections for Canada:[21]

- In general, for every 1°C increase in global temperature, about 5% more precipitation will occur due to a speeding-up of the evaporation process. Extremes of the hydrological cycle (floods, droughts), should therefore become more frequent. Heavy precipitation events could increase in frequency by more than 50% and the intensity by as much as 50%. What are now 20-year return events could become 10-year occurrences.
- A greater frequency of heavy rainstorms and landslides is anticipated, especially in western Canada.
- Recent data indicate much increased forest fires, and threats to many forest-area communities. As much as 30 to 50% of the boreal forest land area could be affected in the next 50 years. In Canada, the number of lightning fires could increase by 44%, and area burned by 78%.
- Winters are likely to be warmer and wetter; summers warmer and drier. In some regions, this could result in reduced snowpacks to feed rivers and water storage reservoirs in summer, possibly leading to power and water supply shortages, as well as increased forest fires, insect infestations and crop damage. In other regions, extreme winter snowfall events are predicted to increase in frequency.
- Evidence for observed changes in drought frequency is not consistent or convincing, but drought frequency and severity in major cereal growing regions of Canada could increase in the future.

[21] Cited in *Implications of Climate Change for Natural Hazards*, a presentation given by James P. Bruce (then Chair of the Canadian Climate Program Board), at the Natural Hazards Society, Toronto, 1996.

- The mean sea level has risen between 10 and 25 cm over the past century. Projections of future rates of increase in a warming world are 2 to 5 times these past rates with a mid-range projection of a 0.5 metre rise by 2100. Estimates are that the world population exposed to coastal flooding would double from 46 to 92 million with a 0.5 metre sea level rise. In Canada, this would affect communities on all three coasts.

V. Disaster Mitigation and Preparedness: Prevention Pays

Despite a great deal of effort and many advances in the mitigation of natural disasters, there continue to be huge losses in human life, injury and property damage every year with the prospect of substantial increases in the future due to climate change and other factors. As discussed above, projections for Canada indicate that extreme weather events will likely increase markedly in almost every area of the country.

Why change? Some are of the opinion that no major actions should be taken until the evidence of climate change is more certain and the link to increased frequency and severity of climate-related natural disasters is verified. However, to delay taking action until the scientific conclusions are confirmed may be extremely risky as irreversible changes may have already occurred and additional enormous economic and human losses may have been suffered through natural disasters which could have been prevented or mitigated against. It would appear that sufficient economic and social benefits may flow from actions that improve disaster prevention and mitigation to justify these activities on their own merits.

A higher priority for hazard prevention, mitigation and preparedness. As society becomes more complex, the economic and societal costs of natural disasters are increasing every year as discussed above. Demographic projections suggest that more and more Canadians will live and work in regions with significant natural hazard risk. The need to encourage timely, cost-effective means to save lives, reduce property damage, and limit disaster costs has never been more apparent, particularly with the prospect of extreme weather events becoming more frequent and severe due to climate change. This calls for a higher national priority for hazard mitigation, prevention and preparedness activities. Clearly, in spite of past efforts, a need exists to renew and improve the framework for setting long-term national goals and the establishment or improvement of technical standards and a system of evaluation of progress.

Losses from weather extremes are not simply something to worry about in the future. Canadians suffer losses from their climate now. While the 1998 Ice Storm, the Red River flood of 1997 and the Saguenay flood of 1996 cannot be directly attributed to climate change, they are consistent with the kind of extreme weather events likely to be associated with the destabilization of the atmosphere and the intensification of the hydrological cycle. Much of the loss suffered as a result of these events reflect the degree and type of measures previously adopted or not adopted. There are also cases of where previous development practices have served to increase human vulnerability to natural disasters (e.g., infrastructure development and modification on floodplains for human

habitation).

Environmental aspects of disasters. The link between natural disasters and environmental pollution is not precise and clear; however, enormous pollution of Canada's air, land and water occurs from forest fires, and during droughts (soil erosion). Water pollutant releases during rainfall and flooding events are greatly increased because of storm sewer inadequacies related to increased paving and higher intensity rains since the mid-1980s. These events may be the largest cause of water pollutant spills[22].

Secondary impacts of disasters. Concern about the cooperation among and the interaction in mitigation activities of parties responsible for public health, food supplies and environmental aspects should encourage a greater degree of mutual support and assistance in these areas at the federal, provincial and local levels. Recent experiences in Canada of floods and recurring agricultural droughts have had serious consequences for individuals, businesses, communities and government treasuries. The secondary effects of severe weather-related disasters can extend to[23]:

- *Human health effects.* An increase in the frequency and intensity of heat waves could lead to more illness and deaths, particularly in sensitive populations in large urban areas in southern Ontario and southern Quebec. An increase in the frequency of severe storms including tornadoes and heavy rains would also lead to an increased number of injuries and deaths.
- *Water resources impacts.* Although Canada has abundant water resources, shortages in some areas already lead to conflicts over partitioning of supply. A warmer climate is likely to have an enhanced hydrological cycle with precipitation falling in less frequent, but heavier events with longer dry periods in between. This is particularly true for the Canadian Prairies.
- *Ecosystems.* Climate change is likely to bring a northward shift of vegetation. This would affect industries, such as forestry and tourism that depend on them. Although there would be productivity gains in some regions, there would be losses in others.
- *Infrastructure.* Most of our buildings, roads and sewer systems are designed for the climate we have experienced in the past 50 years or so. Changes in climate could require changes in design and replacement of buildings and structures before they have outlived their design lifetimes. In the north, structures such as homes and pipelines would be at risk from melting permafrost and slumping land. Increased intensity of precipitation in mountain regions also brings the increased risk of landslides and avalanches.

Risk management: Responses to extreme weather events will require a mix of social and political processes to manage the risks. Better documentation of the available tools

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[22] From Environment Canada's *Summary of Spill Events in Canada, 1984 - 1995*, July 1998. See especially Table 2.2.1.b., and figure 2.2.3.

[23] From the report by the Canadian Climate Program Board to the National Climate Change Secretariat, *Understanding and Adapting to Climate Change*, citing the IPCC report on the "Regional Impacts of Climate Change" and the "Canada Country Study: Climate Impacts and Adaptation".

to analyze and manage certain risks will assist in consistent application. In particular, hazard identification and analysis is needed for all natural hazard events and environmental pollution and technological disasters associated with them.

There are a number of tools readily available for mitigation and prevention of most extreme weather-related events and these include, among other things:

- land use planning and management;
- building codes and standards;
- insurance;
- prediction forecasting;
- warning;
- engineering and;
- new technologies.

Canadians are fortunate to have a National Standard[24] that lays out and explains the iterative and interrelated process of risk management. This well-understood, systematic and science-based process could and should be applied to the prevention, mitigation and preparedness activities related to natural disasters, just as it has been successfully used in managing the risks associated with technological disasters.

Cooperation is the key. Cooperative working groups of stakeholders among public and private sector organizations, particularly key departments of government at federal, provincial/territorial and municipal levels need to come together to examine the application of these tools for the optimum effect. The cost of revising and applying some of the most effective mitigation tools, such as building codes, engineering standards and public works will be a major area of concern and will have be addressed in any national plan. This will be discussed more fully in the following section.

In summary, the likelihood of greater and more frequent weather-related disasters in future could provide impetus to national cooperation in two main activities:

- increased efforts towards improving disaster warning, preparedness and prevention activities under the umbrella of the United Nations International Decade for Natural Disaster Reduction (IDNDR).
- increased actions to limit greenhouse gas emissions to meet or better Canada's commitment under the United Nations Framework Convention on Climate Change (UNFCC).

At the local level, there are a number of things that could be considered which would help prevent disasters, lessen their impact, improve our response or speed up recovery:

- Do everything reasonable at a personal level and within the community to reduce greenhouse gas emissions.

[24] See National Standard of Canada, CAN/CSA-Q850-97, *Risk Management: Guideline for Decision-Makers*, Canadian Standards Association, 1997.

- At the risk management level, use the tools and techniques developed for the risk management process for the prevention, mitigation and preparedness aspects of natural disasters. Reference the risk management national standard, Q850-97, *Risk Management: Guideline for Decision-Makers*.
- Anticipate that severe weather events will be more frequent than has been expected in the past; 100-year flood events may now become 50-year return events and 200-year events, 100. This has important implications for public works such as flood prevention, dyking and berming, sewer design etc[25].
- Assist preparedness activities at the local and municipal levels by encouraging and participating in coordinating meetings and committees, and pushing for action. It should be considered unacceptable that a municipality does not have a tried and tested municipal plan for all relevant hazards.
- Severe disasters often leave the family unit to cope on its own for 24 to 48 hours. It is tragic to note that failure to be able to cope at this level causes many, if not most, of the casualties in the immediate aftermath of a disaster. Public outreach programs should focus on the need to develop this minimal self-sufficiency at the family unit level.

VI. Key Adaptation Strategies for a Changing Climate: Mitigation and Preparedness Concepts

As discussed above, it is now generally accepted that some form of change in our climate is actually occurring and will continue to occur for a number of decades in spite of plans for reductions in greenhouse gas emissions and levels. One aspect to which we must adapt is the increasing frequency and severity of extreme weather events and the associated natural disasters. There are two main reasons for the imperative of adaptation. First, the impacts of climate change, and hence, its danger to society, can be modified by adaptations of various kinds. Second, adaptation is considered to be an important policy option or response strategy to concerns about climate change complementary to reducing net emission of greenhouse gases[26].

Perhaps at this point the meaning of the term "mitigate" or "mitigation" and some of the risk management and disaster management terms should be clarified, since they are used somewhat differently by the climate change and the emergency preparedness communities.

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[25] See Zwiers, The return frequencies will be approximately halved.

[26] Smit, B., Burton, I., Klein, R.J.T.: (1998 forthcoming), 'The Anatomy of Adaptation to Climate Change and Variability', a paper prepared for a Special Issue of *Climatic Change on Societal Adaptation to Climatic Variability and Change*.

Table 3: Terminology

hazard	A source of potential harm, or a situation with a potential for causing harm, in terms of human injury, damage to health, property, the environment, and other things of value, or some combination of these[27].
mitigation	In the climate change lexicon, a mechanism, means or process for reducing the net emission of greenhouse gases or increasing the capacity or number of carbon "sinks" or depositories.
mitigation	In the language of the emergency preparedness community, mitigation means to cause to become less harsh, hostile; severe or painful; to moderate or secondarily, to carry out sustained action to reduce the risk to life, property and the environment from disasters of all types[28].
prevention	An emergency preparedness term meaning an action or actions to keep from happening or forestalling an emergency, disaster, spill or release.
risk	The chance of an injury or loss as defined as a measure of the probability and severity of an adverse effect to health, property, the environment, or other things of value[29].
Risk management	The systematic application of management policies, procedures, and practices to the tasks of analyzing, evaluating, controlling, and communicating about risk issues[30].

Adaptation to climate is not new. Over thousands of years, human societies have successfully adapted to climate in all its variety. This adaptation has been so successful that human beings, unlike any other species, can live and flourish in practically every climatic region on the planet. Climate varies much more from place to place, than over time. Human ingenuity has brought about successful adaptation everywhere. Given that humans can successfully adapt to almost any climate, the main concern about adaptation is because it takes time and may be costly.

Adaptation to our current climate has been carefully and painstakingly built, over decades and centuries, into virtually all designs and practices. The cost of adapting to the current climate in Canada each year is estimated to be over $11.6 billion. So pervasive is this accomplishment that it is scarcely recognized. However, these annual expenditures do not include measures to prepare for extreme weather events.

27 National Standard of Canada, CAN/CSA-Q850-97, *Risk Management: Guideline for Decision-Makers*, Canadian Standards Association, 1997, page 3

28 From the Emergency Preparedness Canada draft paper, *A National Policy for Mitigation*, October 1998.

29 CAN/CSA-Q850-97.

30 CAN/CSA-Q850-97.

Strategies for adaptation of human systems to a changing climate can include technological, economic, legal or institutional mechanisms. Some of the adaptive strategies listed below have existed for many years. However, they have been inadequately or incompletely applied in the past to mitigate the effects of natural disasters. These include, among others:

- Land use restrictions, especially for floodplains, coastal shorelines, landslide-prone areas and other areas considered to be at risk.
- Safety and fire codes for buildings and other structures that could affect the public.
- The adoption of a system for emergency management, including education and training, and public outreach.
- Public prevention and mitigation infrastructure adjustments - dams and weirs, flood channels, dykes, land stabilization works, transmission towers, communication devices and channels, etc.
- Establishing effective programs for post-disaster recovery and support to provincial and local governments.
- Providing public health, agricultural and environmental programs that ensure the survival and effective functioning of critical public services.
- Revised flood plain mapping and codes for snow and wind loading and return frequencies. Adjusting to new realities - e.g.,"200-year" floods become "100-year" floods.
- Disaster response:
  - new responsibilities for emergency services and other agencies to deal with the expected increases in extreme weather events.
  - public expectations and the need for individual and family self-sufficiency for periods of time in the early stages of disasters.
  - changing emergency services structures.
- Recovery - new strategies for continuation of government and business operations. Getting community life back to "normal".

VII. Suggested Next Steps and Some of the Issues They May Create

This section is intended to stimulate thought and discussion about what could or should happen next in the process of considering the implications of a changing climate on prevention, mitigation and preparedness aspects of extreme weather-related events and natural disasters. The views are those of the authors.

Clarifying and confirming the science: There has been, and continues to be, an enormous amount of research in the climate change and severe weather fields. The results of this research will have a huge impact on the emergency preparedness and response communities. There may have to be new processes, mechanisms, alliances and

partnerships developed to ensure that the latest information is disseminated to and incorporated by those who should have it.

Strengthening existing prevention, mitigation and preparedness policies: Significant changes in the frequency and severity of weather-related events should cause changes to codes, regulations, and practices that govern many aspects of our daily lives. Such variables as wind, water and snowloads for building codes, return rates for floods, rain, hail and snow storms, floodplain maps, crop insurance criteria, crop rotation practices, design criteria for municipal structures like sewers and water supplies, engineering design criteria for roads, bridges, dams and other structures and a host of other practices will require substantial modification. Public health practices alone represent a huge area that will be affected by changes to the frequency and severity of extreme weather-related events and natural disasters. The process of changing these codes, standards, practices etc. will likely be very difficult, divisive and expensive.

Emergency preparedness is central to the protection of populations and infrastructure in natural disasters. What may be needed in Canada is a new and comprehensive national emergency preparedness strategy developed by the federal and provincial/territorial governments and supported enthusiastically by municipal and local governments.

Adopting the risk management process. The risk management process as defined and laid out in the new National Standard of Canada, Q850-97, *Risk Management: Guidelines for Decision-Makers,* presents an opportunity for adoption by the emergency preparedness community as a comprehensive process for managing the risks associated with climate-related natural disasters. This process includes some of the successful practices currently used by preparedness professionals, such as hazard identification and analysis. However, it adds new aspects such as risk assessment, risk control and risk communications which could greatly benefit the preparedness process. The risk management process emphasises the iterative nature of the whole process that is an important aspect of emergency preparedness.

Engagement of key stakeholder groups: To date, the issues surrounding climate change have involved specialized groups such as climate scientists, environmental groups, some levels of government and various private sector interests (including the insurance and reinsurance industry, and the energy sector). The groups are dominantly those who have perceived identifiable threats from climate change issues but who are also largely driven by the global warming agenda. Similarly, the issues surrounding weather-related natural disasters have their own proponents. They are primarily the concern of preparedness and response organizations at the federal-municipal level, non-governmental organizations, the agriculture and agri-food sectors and the transportation sector, among others. Historically, there has not been a lot of common ground between the agendas of the two groups, i.e., of adaptation to climate change and mitigation of weather-related natural disasters. There is considerable scope for engagement of these two groups, plus a broader community, to work simultaneously on the issues - the common ground is risk reduction.

Identifying additional issues or special themes: Some have characterized the impact on human civilization of a changing climate to be more profound than the atomic era or the information age. Even if this is not the case, there will be many issues, which may warrant workshops or future research. It will be important for the engaged and enlightened stakeholder groups to maintain a watching brief so that policies and strategies can be adjusted to changes in predictions and outcomes. Some of the additional areas that could warrant priority attention include:

- *Environmental pollution aspects* - natural disaster-related spills and releases of pollutants into air, water and land systems.
- *Health impacts* - weather-related disaster mortality, infectious and epidemics, respiratory diseases related to poor air quality.
- *Agricultural and agri-food aspects* - disaster-related damages, irrigation requirements, crop yield, crop diseases and infestations.
- *Forest concerns* - increases in forest fires and other damages, changes in forest compositions, and geographic range, forest health and productivity.
- *Water resources concerns* - susceptibility to disaster-related changes, changes in water supply and quality, increased competition for supplies.
- *Coastal area aspects* - flooding of coastal lands and communities, damage to coastal infrastructures and shore erosion.

Making changes. People are not generally interested in "emergencies" in normal times and tend to deny that there could be problems. In a crisis, governments see their role as "rescuer" or "helper". Immediately following an emergency or crisis, the political level is more favourably disposed to making changes to the emergencies or risk management system. Emergency preparedness professionals who wish to make changes to the emergencies or risk management system should consider having all the ground work done for desired changes in advance with the intention of obtaining approval from the political level when conditions are right - that is, immediately following a disaster.

There will be large economic and social benefits in increasing and improving disaster preparedness and mitigation efforts. As the rising trend in the frequency and severity of weather-related events and the associated destruction, damage, injury and loss of life clearly indicates, improved disaster preparedness and mitigation is an imperative in a changing climate.

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